

# Microscopical Comparison of Cotton, Corn, and Soybean Dusts

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Specialized analytical methods are required for identification of components of agricultural dusts such as those generated in harvesting, transportation, storage, and processing of cotton, corn, and soybeans. The larger particles and trash components of the dusts can often be identified visually or with the aid of an optical microscope (OM). The respirable portion of the dust, that which causes lung dysfunction, retains few structural features for identification. Electron microscopy and X-ray microanalysis, together with special optical microscopical techniques, can be used to characterize these microdusts. Combination studies with scanning electron microscopy (SEM) and energy-dispersive X-ray (EDX) analysis of cotton dusts have shown the presence of mineralogical particles probably of a soil origin and materials that can be associated with plant parts. Even in screened and filtered cotton dusts, fibrillar fragments are usually present due to their ability to penetrate openings the size of their diameters. The corn and soybean dusts studied were different from the cotton dust in that the large fibrillar component of the cotton dust was absent in the screened grain dusts. However, these dusts consisted of structurally unrecognizable particles that appeared similar to those found in cotton dust. In addition they contained many spheroid particles identified as starch. Dusts from all three sources were found to agglomerate into larger particles, some of which were still  $< 10 \mu\text{m}$ . This agglomeration could confuse the instrumental measurement of dust particle size.

## Introduction

Health hazards produced by agricultural dusts have generated great interest in the identification and characterization of the dust materials. Microscopical particle analysis provides a means for study of individual particle morphology and chemical composition. Optical microscopy (OM), scanning electron microscopy (SEM), and energy-dispersive X-ray (EDX) analysis have been used to study dusts generated in processing cotton, corn, and soybeans. Most particles less than  $15 \mu\text{m}$  are difficult to identify structurally if they have been produced by breaking up of larger particles or if surface features have been smoothed by abrasion. EDX elemental analysis, correlated with SEM, provided information valuable in determining particle source and size of particles in agglomerates.

Components of cotton dusts may vary with factors such as growing area and location of dust collections in the mill. However, components usually are largely plant parts, soil particles, fungi, bacteria, pollen, and fiber fragments. Respirable-size particles of these materials

are difficult to identify. Bacteria, fungal spores, pollens, and larger fiber fragments are identifiable microscopically. Most plant and soil particles cannot be identified visually and special techniques are required to determine their sources.

Grain dusts consist of components of the grain and plant stalk, soil particles, chemical residues, insect and rodent materials, and fungi and bacteria. Composition may depend on whether the dust was produced during harvesting or storage processes.

## Materials and Methods

Cotton dust used for these comparative studies was collected by a condenser wash system from the opening and carding areas of a textile mill. The collected dust was sonically sifted and fractions  $< 30 \mu\text{m}$ ,  $< 20 \mu\text{m}$ , and  $< 10 \mu\text{m}$  were studied. Leaf and bract materials were obtained from Stoneville 213 and Pima S-5 cotton plants grown at SRRC.

Corn dust was collected from settlement on a tripper at the top of a silo bin where corn was being unloaded from trains and barges. Soybean dust was removed from supports in a sixth floor cleaning tower where soybeans

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were being handled. Both dusts were sieved through 40-mesh screens before being studied.

For SEM, dusts were sprinkled onto adhesive-coated specimen stubs or onto uncoated carbon disks when EDX analyses were to be made. Live leaf and bract materials were chemically fixed, freeze-fractured, and critical point dried (1) before mounting on SEM stubs. Samples for

SEM were coated with gold/palladium for charge suppression and those for EDX analysis were carbon coated. Optical microscopy was carried out on mineral oil-mounted slide preparations. Hubner's reagent ( $I_2$  in KI solution) was used to stain for starch. Quantitative elemental analyses were made on bulk samples by X-ray fluorescence measurements.

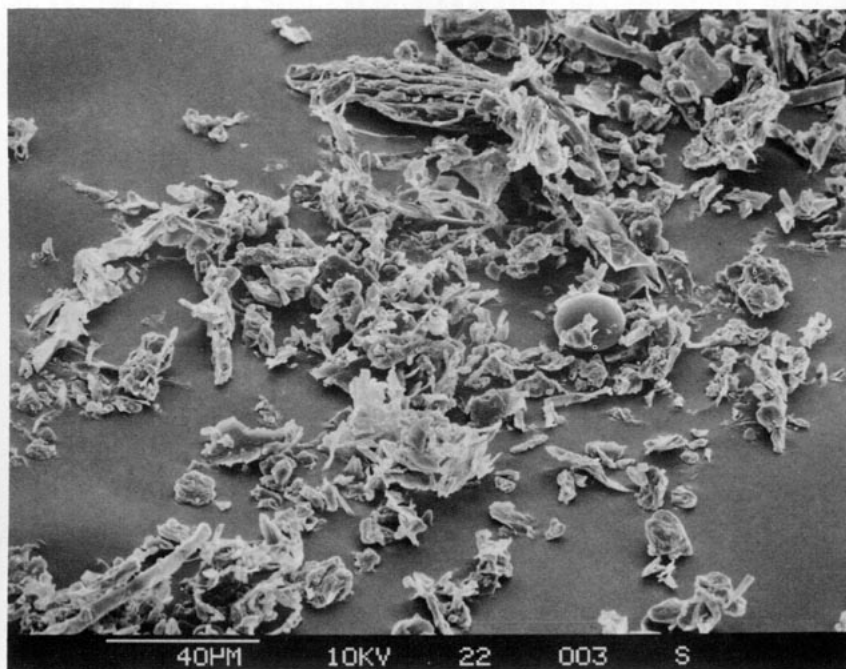


FIGURE 1. Cotton dust sifted to  $\leq 10 \mu\text{m}$ .

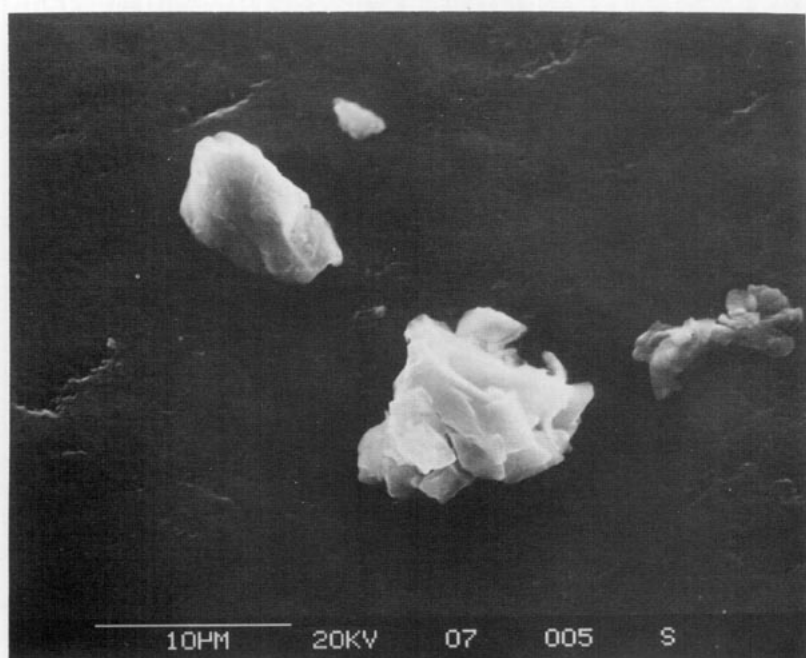


FIGURE 2. Calcium oxalate crystals in cotton leaf material.

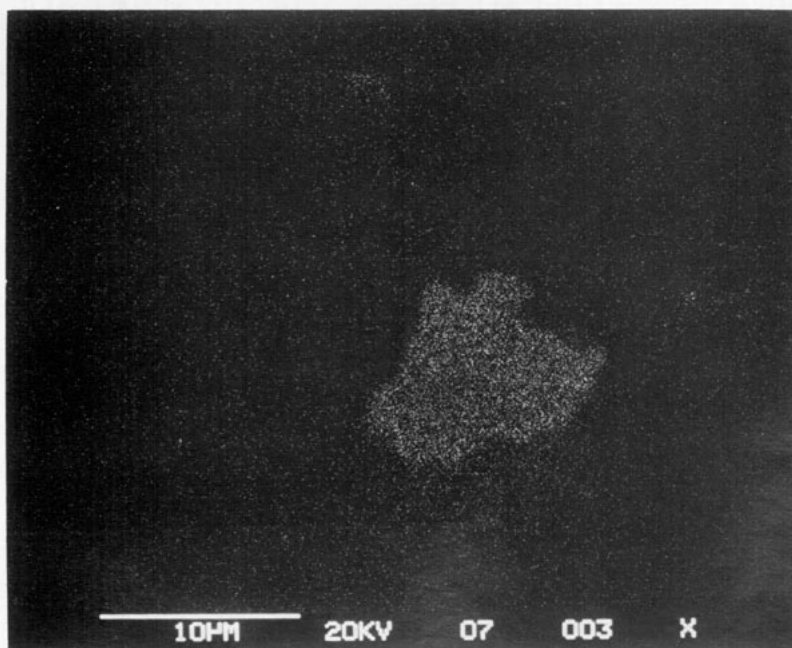
## Results and Discussion

Mill-collected cotton dusts contain a large fraction of fiber fragments. These can range in length from several millimeters to several micrometers and may be simply broken fibers or fibrillar fragments. It also contains large

pieces of plant material, both cotton and noncotton (2). Sifting and sieving of whole dusts separate the larger trash particles from the true dusts. Some particles larger than these cutoff sizes were found in each fraction due to arrowing of particles with a greater length dimension. Figure 1 illustrates cotton dust sifted to  $\leq 10 \mu\text{m}$ . In-



*a*



*b*

FIGURE 3. (a) Calcium oxalate fragment isolated from cotton dust; (b) calcium EDX map of fragment.

**Table 1. Results of X-ray fluorescence analyses of the dusts for selected elements.**

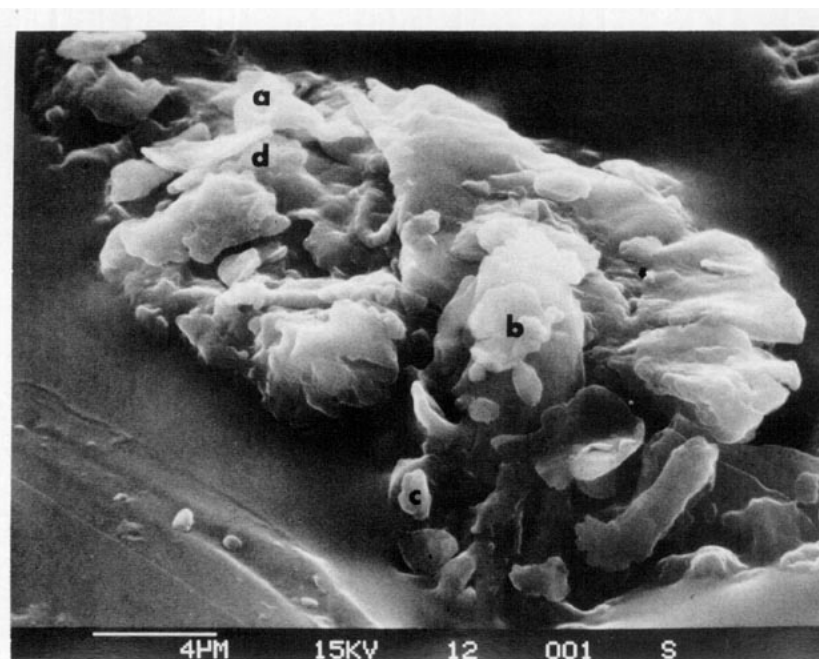
Element	Composition of various dusts, %		
	Cotton	Corn	Soybean
Magnesium	0.87	$2.38 \times 10^{-5}$	$4.08 \times 10^{-5}$
Aluminum	1.59	0.56	1.23
Silicon	2.87	1.69	3.83
Phosphorus	0.31	0.09	0.26
Sulfur	0.61	$1.6 \times 10^{-5}$	$1.6 \times 10^{-5}$
Chlorine	0.75	0.06	0.07
Potassium	1.39	0.42	0.75
Calcium	2.61	0.29	0.51
Iron	0.21	0.29	0.37

dividual particles are generally irregular in shape and their source is unidentifiable, except for fiber fragments, fungal spores, and pollen grains that are occasionally found.

Elemental analyses of whole dusts show the presence of specific elements but reveal little about individual particles. EDX analysis in association with SEM makes possible the determination of certain elements within individual particles. Mineral materials, specifically silicates, and calcium, potassium, and aluminum compounds have

been found. The relatively high calcium content of cotton dust (see Table 1) has been shown to derive in part from calcium oxalate crystals stored in cotton leaf and bract material (1). Figure 2 is a fractured leaf showing a row of calcium oxalate crystals. Ingestion of plants with high calcium oxalate content produces toxic effects in animals. Fragments of these crystals have been found in mill-collected cotton dust. A crystal fragment isolated from cotton dust is shown in Figure 3a and a calcium EDX map of the fragment in Figure 3b.

Many dust particles that appear to be a single particle at lower magnification are seen as agglomerates at higher magnification. Agglomeration is easily detected in some particles and in others is more subtle. Figure 4 shows two (or more) larger particles to which numerous smaller particles are attached. Viewing such particles from different perspectives by changing the specimen holder tilt makes it more evident that they are agglomerates. Additionally, EDX analyses performed on different areas of the sample indicate that the various smaller particles show variations in elemental content. This is illustrated in Figure 5. The EDX elemental spectra were obtained from the indicated areas on the particle. While these different elemental spectra may not be completely accurate for each microparticle due to interference from other surrounding materials, the great differences do indicate

**FIGURE 4.** Agglomerate cotton dust particle.

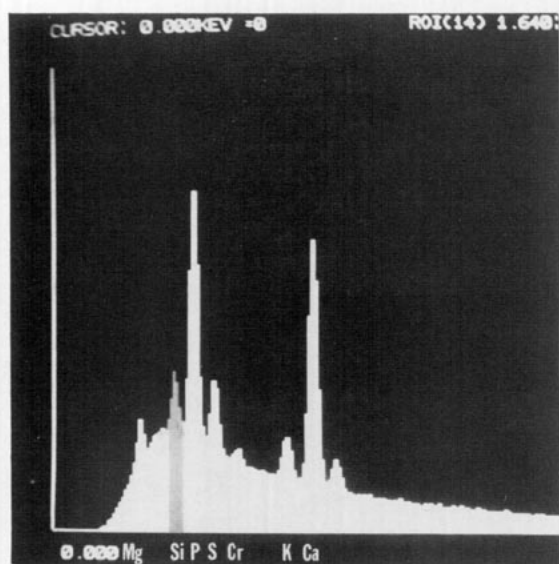
that the "particle" is a cluster of different particles.

Particles suspended in the air during transfer processes of grain are called grain dust, which may contain both organic and inorganic materials. When received at the elevator, grains commonly contain trichomes (plant hairs) and fine dusts. The fine dust may originate from soil, weeds, insects, or grain (3). Fragments of fungi, bacteria, pollen, mites, rodent hair, and excreta, plant parts, soil materials, and the grain itself have been identified (4).

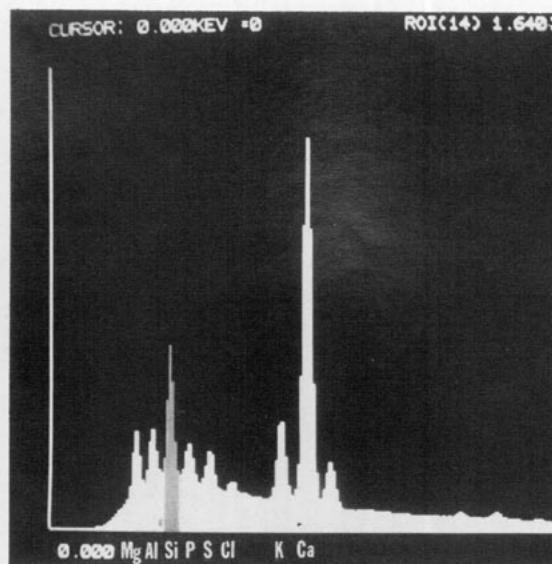
Characterization of grain dusts in this study has not

been nearly as extensive as has that of cotton dusts, but was made to determine whether there are gross morphological differences in the dusts that would distinguish them. Elemental analyses of cotton, corn, and soybean dusts by X-ray fluorescence for nine elements are shown in Table 1. These results show that quantities of these elements are greater in cotton than in either corn or soybean dusts, except for silicon and iron. Soybean dust had the highest silicon and iron content.

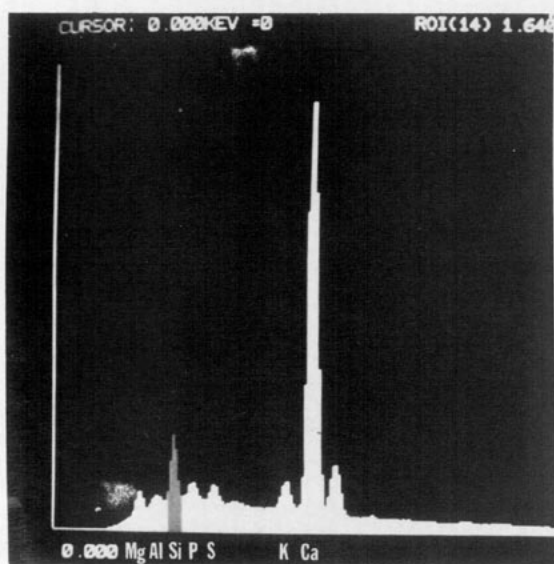
Scanning electron microscopy of corn dust showed the fine fraction to contain unrecognizable particles just as



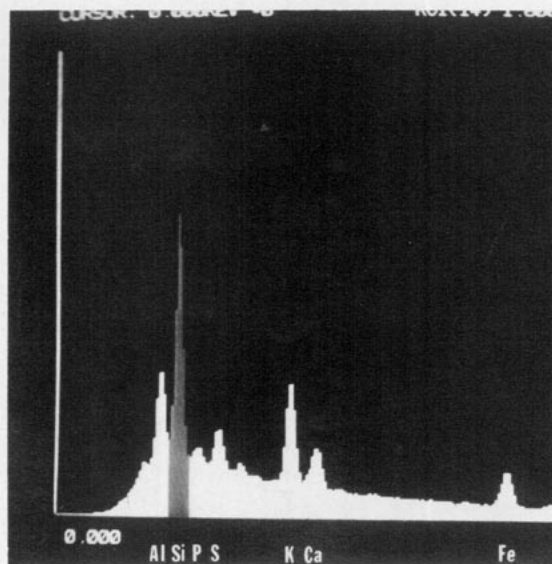
a



b



c



d

FIGURE 5. EDX spectra from areas a, b, c, and d, of Fig. 4.

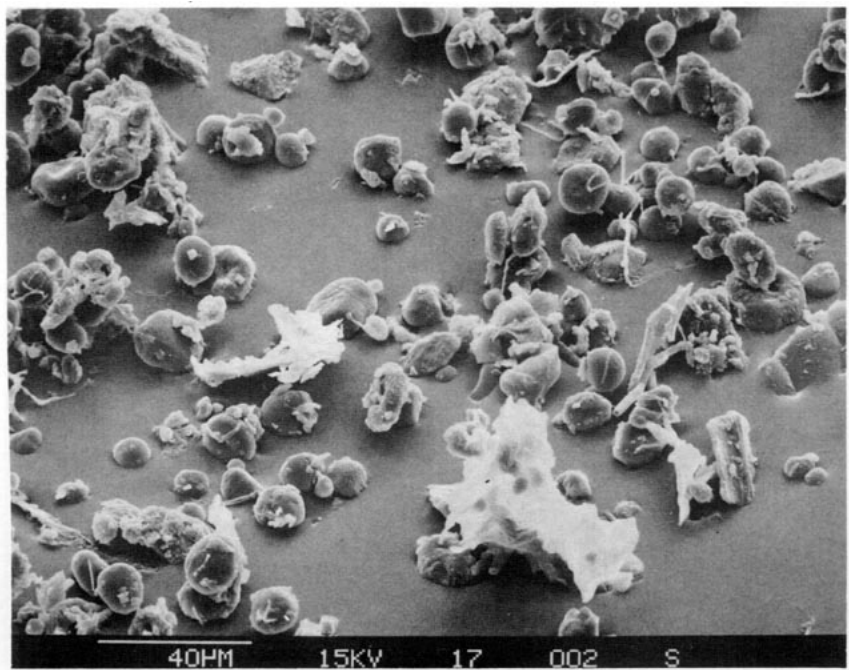


FIGURE 6. SEM of corn dust.

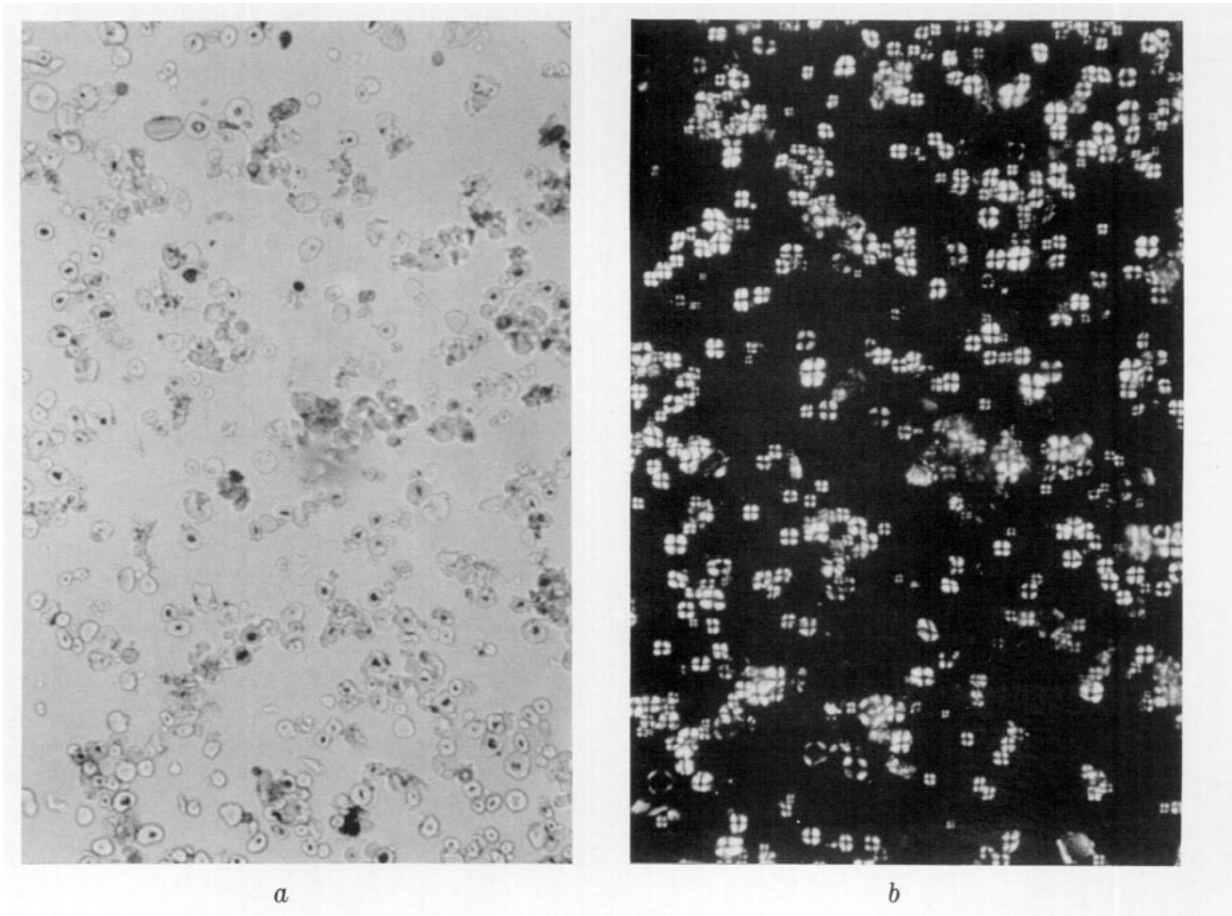


FIGURE 7. Optical micrograph (a) and polarized light micrograph (b) of corn dust.



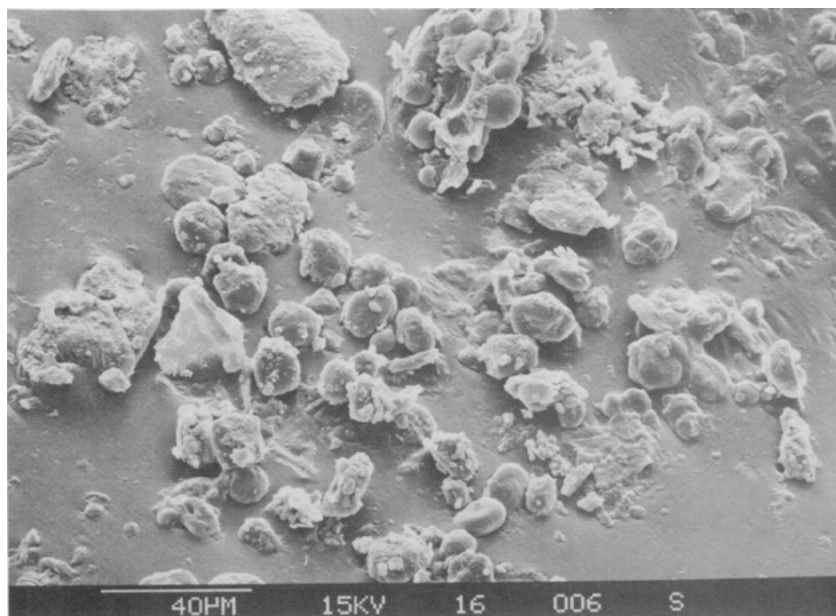


FIGURE 8. SEM of soybean dust.

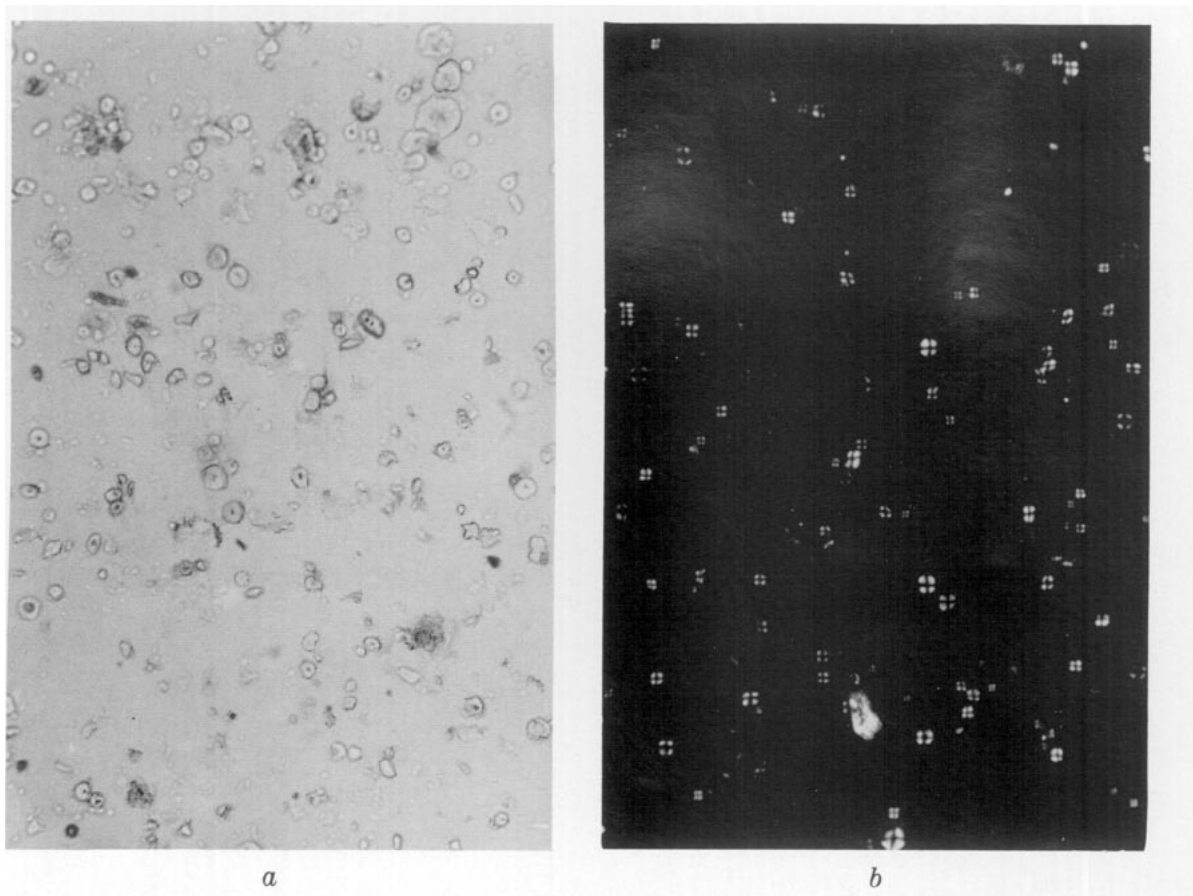


FIGURE 9. Optical micrograph (a) and polarized light micrograph (b) of soybean dust.

cotton dust does. However, it also was composed of a larger number of rounded particles shown in Figure 6. Polarized light microscopy confirmed that these particles

were starch grains. Figure 7 compares a micrograph of corn dust with the same field seen with polarized light. Starch grains are identified by the Maltese cross for-

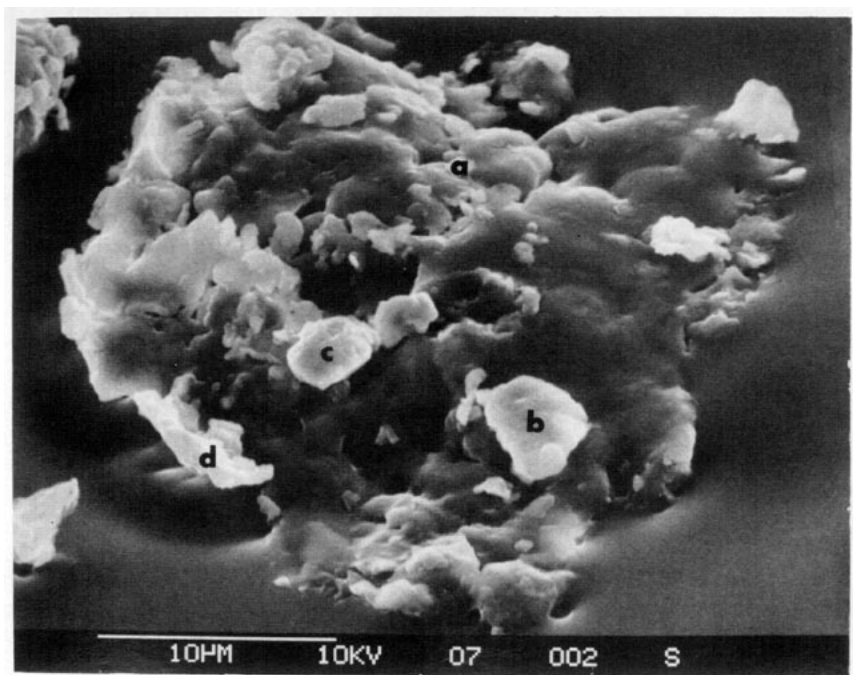
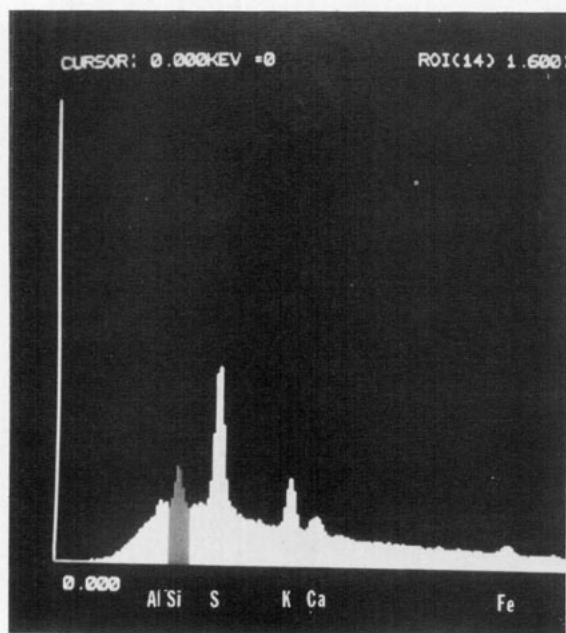
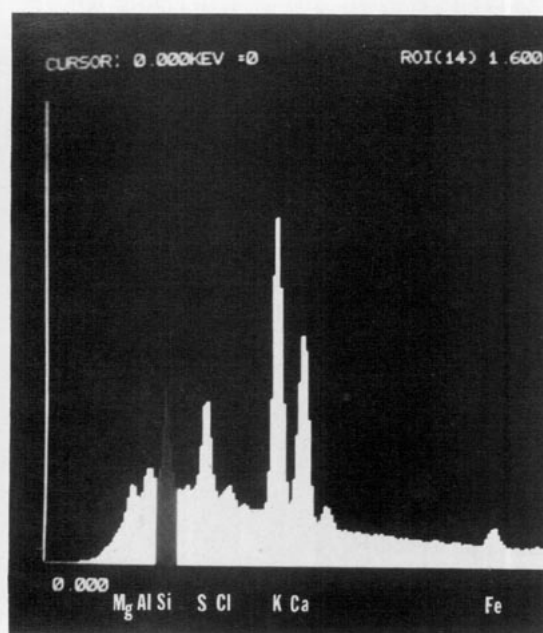


FIGURE 10. Agglomerate soybean particle.



a



b

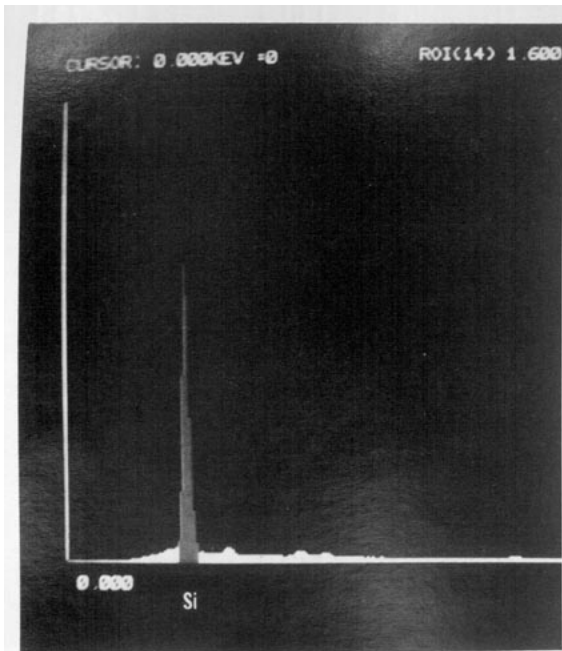
FIGURE 11. EDX spectra from areas a, b, c, and d, of Fig. 10. Figs. 11c and d are on the following page.

mation. This comparison shows the large percent of starch particles in the sample. Staining of the dust with iodine solution stained the rounded particles deep blue, also identifying them as starch.

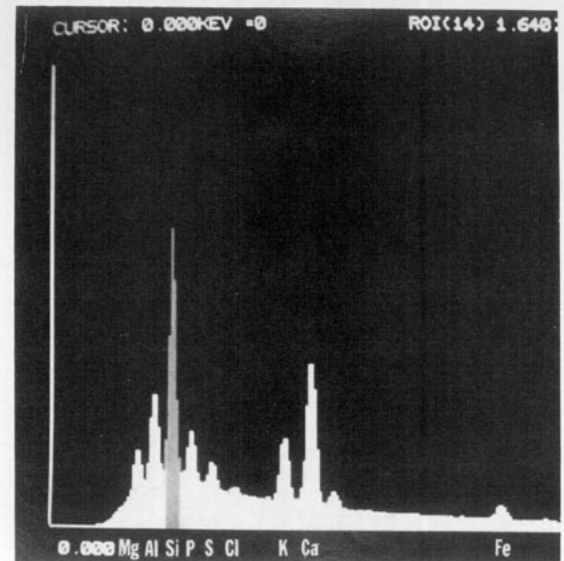
In the SEM, soybean dust appeared similar to corn dust except the number of rounded particles was less.

Figure 8 illustrates an SEM image of soybean dust showing some rounded particles interspersed with irregularly shaped materials. Figure 9 compares an optical micrograph with the polarized light micrograph of the same field. Starch particles again appear with Maltese crosses. Comparison of Figure 9 with Figure 7 of corn dust in-





c



d

indicates that the starch content of the corn dust is greater than that of the soybean dust.

Particle analysis measurements were carried out on an image analysis system, equipped with a polarizing light microscope, to determine relative amounts of starch in the corn and soybean samples. The field area fraction of particles considered to be starch, based on shape and polarized light characterization, was 43.5% for corn and 27.4% for soybean. These percentages were calculated as total area of starch particles divided by total area of particles, and are in general agreement with SEM observations.

Dust particle agglomerates similar to those found in cotton dust were found in both corn and soybean dusts. Figure 10 shows an agglomerate soybean particle typical of those in both corn and soybean dusts. Figure 11 shows EDX elemental spectra from different areas on the particle.

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